Sustainable Development Law & Policy

Volume 9
Issue 3 *Spring 2009: Clean Technology and International Trade*

Article 12

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*by Craig A. Hart & M.L. Rajora**

Introduction

Biomass offers a potentially ideal source of fuel for cleaner power generation and the support of sustainable development in developing countries.[1] It is the fourth largest source of primary energy in the world and the largest source of renewable energy, supplying about ten percent of 2004 total primary energy supply.[2] Biomass could account for in excess of thirty percent of the world's primary energy by the year 2050.[3]

Biomass power generation technology is mature, yet deployment of this technology on a wide scale faces significant institutional barriers related to the difficulty associated with sourcing a reliable and affordable supply of biomass. Biomass power production at a large scale also poses significant water and food security issues if not managed properly.

The authors review China and India's laws and policies regarding biomass supply in order to assess their institutional arrangements for application of biomass technology. We selected China and India for study because they are the world's largest countries in terms of population, their economies and energy demand are rapidly growing, and they have large agricultural sectors. Biomass will be increasingly important to these countries as they seek to meet energy demand in a sustainable manner.

This article examines the advantages of biomass energy for developing countries; the barriers posed by difficulty in obtaining an economical, adequate, and reliable supply of biomass; and how China and India have prepared for biomass generation by addressing these barriers through legislation. It describes policies and programs developed by China and India to encourage expansion and integration of this important technology into the existing energy infrastructure.

Advantages of Biomass for Developing Countries

In developing countries, biomass typically accounts for as much as twenty to thirty percent of energy supply and in a number of countries can reach fifty to ninety percent of total energy supply.[4] In these countries, biomass is used as the primary source of energy for home heating and cooking in rural areas.[5] However, the burning of biomass, which typically occurs in enclosed areas, poses threats to human health, and is a primary cause of respiratory diseases in developing countries.[6]

Biomass electricity generation can provide household energy without the adverse health impacts of using biomass directly in homes. Further, biomass power generation can significantly reduce sulfur dioxide and nitrous oxides, mercury, particulate emissions, and greenhouse gas ("GHG") emissions compared to coal power plants.[7] Coal currently supplies eighty percent of China's power,[8] and sixty-nine percent of India's power.[9] As is well-known, pollutants from coal power plants cause serious health effects, such as birth defects, as well as cancer and respiratory illness; they also pollute land and water and poison food supplies.[10]

Biomass power generation can significantly reduce sulfur dioxide and nitrous oxides, mercury, particulate emissions, and greenhouse gas emissions.

Biomass power generation can also help reduce the use of chemical fertilizers in agricultural production and promote the development of organic agriculture. The ash product of a biomass power plant can be processed into fertilizer for use by farmers. In turn, the greater reliance on organic fertilizers can reduce the negative effects of chemical fertilizers on soil and ultimately significantly promote water conservation.[11]

For China, estimates for the amount of agricultural biomass available range from approximately 250 to 376 million tons per year, out of a total of approximately 726 million tons of crop residue generation.[12] This could supply cooking fuel for over half a billion people.[13] China's forests produce additional bio-

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Crop	Production Million Tons of main crop	Types of Residues	Production of main crop to residue ratio	Quantity of residues in Million Tons/yr	Typical Uses of Residues
Rice	90	Straw	1.3	117	Used as cattle feed in Southern and Eastern India. Generally burnt in the fields in the North.
		Husk	0.3	27	Used as a fuel by small industry.
Wheat	80	Straw	1.5	120	Used mainly as cattle feed.
Coarse Cereals	30	Straw and Husks	1.8	54	Used as cattle feed and as fuel.
Sugarcane	320	Bagasse	0.3	96	Mainly as a captive fuel by sugar plants, partly as raw material for papermaking.
		Tops	0.05	16	Used as cattle feed
		Trash	0.07	20	Mostly burnt in the fields.
Coconut	14 billion nuts	Shell Fibre	0.13 kg/nut 0.2 kg/nut	0.2 2.8	Partly as domestic fuel. Used partly, for making mattresses, carpets, etc.
		Pith	0.2 kg/nut	2.8	No productive use. Disposal is a problem.
Cotton	3.5	Stalks	3.0	10.5	Partly as domestic fuel
		Gin Waste	0.1	0.35	Used as a fuel for brick making and by small industry.
Oilseeds	20	Straws and husks	1.1	22	
Pulses	14	Straws	1.3	18	Partly as a domestic fuel
Jute/Mesta	2.0	Stalks	2.0	4	Used partly as fuel for processing tobacco leaves/domestic fuel
Total				**499**	

Figure 1: India's Estimated Annual Biomass Production

Source: Ministry of Agriculture, Government of India. *Note: Based on 2006–2007 production.*

mass residue of about 24.77 million cubic meters per year using sustainable forest management practices.[14]

For India, biomass has long been the main energy source for cooking and heating. India produces approximately 500 million tons of biomass per year.[15] Biomass has emerged as an increasingly attractive option for power generation due to the growing demand for power, recurrent power shortages throughout the country, a projected shortage of coal for power generation, and the high cost of diesel and other fossil fuels.

Biomass electricity generation plants could potentially help farmers by providing supplementary income from their farm waste to aide in stabilizing farming communities and land use patterns and provide permanent and seasonal employment in rural areas. Biomass for electrification should be integrated into existing property and cultural patterns without requiring the consolidation of small farms into larger operations.

If planned properly, biomass power plants should be able to use only waste biomass that would not require additional water or displace food crops. Further, biomass plants using waste should favor food security by increasing income to rural farmers and keeping land in production. However, if the adoption of biomass power generation changes indigenous agricultural practices, the biomass power plant could potentially require additional water resources or require land that otherwise would produce food to convert to fuel production.

Barriers to Biomass as a Fuel for Power Generation

The primary barrier to biomass power generation is the ability to obtain adequate supply of biomass at an economical price. In developing countries, there is typically no organized market for biomass fuel.[16] As a result, there is no price consistency for biomass material. Lack of transportation infrastructure and the cost and availability of transportation fuels limit the development of regional markets, resulting in fragmented and localized biomass markets.[17] The seasonal nature of biomass material, the variation in quantity, and the low density of such material further complicate the development of an organized market for biomass.

Biomass also faces significant transaction costs resulting from the quantities of biomass required to be collected from large numbers of farms.[18] Contracts with small farmers for a guaranteed supply of biomass would not likely be commercially practicable or enforceable, given that natural conditions play a major factor in biomass production and enforcement costs would be prohibitive.

Further, biomass electricity generation competes with many other uses of biomass. As noted, in developing countries, biomass is commonly used for home heating and cooking in rural areas, and it is burnt by farmers to help fertilize growing fields.[19] Other sources of competition include use by ranchers as a source of feed for livestock, use as a source of supply for construction materials such as bricks and roofs, and use by the paper industry as a source of material for making paper.

In addition to market barriers to biomass, there are also environmental and resource barriers. For example, the availability of water for growing crops such as sugarcane or for cooling a power plant can limit the introduction of biomass power generation in certain geographic areas.[20]

Biomass Supply and Cost Impacts on Project Financing

Biomass supply requirements for a small-size power plant are substantial. The financial performance of a biomass plant is highly sensitive to the cost of biomass supply. In order to assess the risks associated with fuel supply, we conducted a financial analysis based on the retrofit of a coal plant to a biomass-fueled combined heat and power plant in China.

The financial analysis assumes electricity is priced based on preferential rates provided pursuant to China's Renewable Energy Law, but that no additional subsidies are considered. The project financial analysis further assumes that Clean Development Mechanism certified emission reduction certificates are sold by the project for 90 renminbi ("RMB")[21] per metric ton carbon dioxide for a three-year period.

We calculate that a combined heat and power biomass power plant with energy capacity of 24 Megawatts ("MW") requires 270,000 tons of straw (assuming a moisture content of twenty-five percent) per year. Such a power plant would require three ten-ton truckloads of biomass every hour continuously in order to operate at full capacity.

Based on the average size of farm in China (approximately 3 mu, or 0.002 square kilometers), we estimate that each farm produces 1.2 to 1.8 tons of straw per year, and that the power plant will require straw from an average of 180,000 farms. In our example, supply must be sourced within a 75 km radius of the plant so that transportation costs are acceptable, however the cost and risk to the plant increases with distance. A plant operator would likely require much shorter distances to ensure profitability. Further, in terms of sustainability, we estimate that more than half of all transportation related carbon emissions in biomass production can be avoided if the supply is located within 25 km of the power plant.

In rural China, the average annual income in 2005 was 3,255 RMB per year. If straw could be sold for 125 RMB per ton, we estimate that the average farm supplying 1.5 tons of straw per year could increase their annual income by almost 200 RMB/year, an increase of almost six percent that could be very helpful to a low-income household.

The project's financial performance is highly sensitive to the price of straw. For our hypothetical 24 MW project, a 25% increase in the price of straw reduces the project's the internal rate of return ("IRR") on equity from 28.4% to 21.5% and the debt service coverage ratio ("DSCR") from 2.25 to 2.02, assuming a 70% debt-to-equity ratio. In contrast, a one million RMB increase in initial costs slightly decreases IRR on equity from 28.4% to 28.3%, and the DSCR from 2.25 to 2.24.

While our example still shows very good returns, the increase in straw price can result in a significant reduction in profit, and ultimately cause a marginal project to fail. If the market is thin or fragmented, as is typical, the potential for local biomass prices to spike as a result of the introduction of a biomass power plant are real and could render the project uneconomic.

Plant Size	3 MW	6 MW	12 MW	24 MW
Best Case (assumes Straw Price 130 RMB/Ton)				
IRR Equity %	27.8	14.2	23.0	28.4
DSCR	2.19	1.69	2.03	2.25
Initial Cost (RMB millions)	114	183	315	547
Straw Price Increases 25%				
IRR Equity %	24.3	8.9	17.0	21.5
DSCR	2.07	1.52	1.83	2.02
1 Million RMB Increase in Initial Costs				
IRR Equity %	27.5	12.1	22.2	28.3
DSCR	2.15	1.60	2.00	2.24
Effect of each 1 million RMB increase on IRR	–0.3	–2.1	–0.8	–0.1
Effect of each 1 million RMB increase on DSCR	–0.4	–0.9	–0.2	–0.1

Figure 2: Financial Analysis of Combined Heat and Power Biomass Power Plant in China

Source: Craig Hart, China Biomass Combined Heat & Power Multi-Stakeholder Negotiation, Energy + Environment OpenCourseWare, http://eeocw.org/environmental-negotiation/china-biomass-combined-heat-and-power-multi.

Note: The improvement in financial results for a 3 MW power plant results from the use of more efficient technology that is currently only available on smaller scales.

Policy and Regulatory Frameworks in China and India

We review China and India's laws and policies regarding biomass supply in order to assess their institutional arrangements for application of biomass technology.

China

China's National Development Reform Commission set targets for development of renewable energy, including 30 GW of biomass renewable energy to be built by 2020.[22] In support of this goal, the country has developed a series of laws, regulations, and policies with the intention of achieving this substantial increase in biomass use.

China's Renewable Energy Law supports various kinds of renewable energy, including biomass, through a system of preferential electricity prices that vary on a regional basis.[23] The law also provides additional payments for electricity generated with low sulfur emissions.[24] Subsidies for biomass electricity and desulfurization abatement equipment terminate after 15 years.[25] The Renewable Energy Law guarantees sale of renewable electricity to the power grid.[26]

China also offers various financial incentives for biomass. This includes subsidies supporting R&D, low interest loans to projects, and grants to rural households for wood-stoves and bio-gas systems.[27] China also provides tax incentives, including reduced customs taxes for imported equipment and an income tax holiday for industries whose main inputs are wastes.[28]

All land and natural resources in China are owned by the state, and leased to land users. China's property laws and regulations do not, to our knowledge, contain any provisions providing for biomass to be supplied to power generators. China does, however, forbid the direct burning of crop residues within the vicinity of roads, and railway and transportation infrastructure.[29] The measure is intended to increase the utilization of crop residues as fertilizer, materials for industrial use, and straw and stalk gasification.

China's Ministry of Finance issued the Interim Measures for Administration of Special Funds for the Development of Renewable Energy in May 2006 to fund studies, standards formation, resource surveys, production of equipment, and construction of projects in remote areas in the field of renewable energy, including biomass and biofuels.[30] The funds provide both cash appropriation and subdidized loans. The Ministry of Finance and the Ministry of Construction issued the Interim Measures for Administration of Special Funds for Using Renewable Energy in Construction in September 2006.[31] This fund provides financial support to renewable energy, including biomass, used in construction of buildings, such as biomass energy to be used for heating and cooling systems, hot-water supply, electricity for lighting, and cooking.[32]

The Ministry of Finance issued the Notice of Interim Measures of Administration on Subsidy Funds for Using Straw as Energy Resource in 2008.[33] This "Special Fund for Straw" supports enterprises that convert crop straw into energy, including densification briquetting fuel, straw gasification, and straw carbonization. In Chinese law, straw includes paddy rice, wheat, corn, legumes, vegetable material that can be pressed to extract oil, cotton, and tuber crops and remains produced during the initial processing of crops. To be eligible for support from the Special Fund for Straw, the following requirements must be satisfied:

- Enterprise must have registered capital of RMB 10 million or more;
- Enterprise's utilization of straw as energy resource conforms to local regulations governing general utilization of straw;

CASE STUDY: CHINA

China's Microturbine Approach to Biomass Technology[1]

The Research Center for Energy and Power of the Chinese Academy of Sciences is developing an innovative approach to distributed biomass utilization for rural electrification, heating, and cooking by adapting the technology to conditions in the biomass market. The approach uses local small-scale pyrolysis facilities to convert biomass to synthetic gas and active carbon ("char"). Pyrolysis is a thermo-chemical process that breaks down biomass, waste, or other substances by heating it to high temperatures (e.g., 300°C to 500°C for various types of biomass), leaving only carbon residue at certain temperatures.[2]

The synthesis gas produced from the pyrolysis process would then be used for home heating and cooking (replacing direct burning of biomass), and as a fuel source for distributed electric power generation. The approach relies on distributed power plants using micro-scale gas turbines (approximately 100 KW in size) and gas engines. We estimate that a 100 KW gas turbine could require less than approximately 1,500 tons of biomass per year to operate (assuming biomass has twenty-five percent moisture content). The much smaller biomass supply required for a microturbine reduces the risks associated with larger biomass power generation facilities. The active carbon produced from the pyrolysis process can then be used as a natural fertilizer, replacing chemical fertilizers. In addition to increasing agricultural productivity, active carbon also increases the soil's carbon absorption.

1 Source: Interview with Dr. Xiao Yunhan, Professor of the Chinese Academy of Sciences and China's Ministry of Science & Technology (Apr. 17, 2009).

2 Pyrolysis is widely used to convert waste into safely disposable substances, to produce various chemical products, to crack hydrocarbons in the refining processes, and to produce biofuels from animal wastes.

- Enterprise's annual straw consumption is at least 10,000 tons; and
- Enterprise's products are commercialized and has stable customers.

China's energy technology subsidies programs are intended to increase the efficiency of biomass power generation and integrate it with buildings (a major power user), which will help make biomass power generation less expensive and more financially stable. The Special Fund for Straw is intended to directly address the risks associated with biomass supply. However, these subsidies are likely to be temporary in nature. Thus, the long-term strategy should be to increase efficiency of biomass technologies, and to adapt technologies to the conditions of the biomass market.

India

In 1981, India created a government commission with overall responsibility for developing renewable energy and a separate Department of Non-Conventional Energy Sources in the Ministry of Power that eventually evolved into the Ministry of New and Renewable Energy.[34] The Ministry of New and Renewable Energy issued the Renewable Energy Power Purchase Guidelines to all States in 1993, followed by the Energy Conservation Act of 2001, which mandated adoption of standards and procedures and prescribed measures for energy conservation.[35] The Electricity Act of 2003 guaranteed interconnection for renewable energy sources and provided recommendations for preferential tariffs and quotas for renewable generation.[36] Almost all states have implemented some form of preferential tariffs for renewable energy generation, and have set general quotas for renewable energy, but have not specified quotas by energy type. The amount of subsidies depends upon the type of technology used in the project and the equipment's level of efficiency.[37] These measures have been strengthened by the National Electricity Policy of 2005, the Tariff Policy of 2006, the Rural Electrification Policy of 2006, and the Integrated Energy Policy Report of the Planning Commission of India in 2006.[38] Today, India's power market mostly comprises regulated prices with a few states introducing open bidding on electricity through ten to fifteen year power purchase agreements.

In addition to preferential rates specified by the state regulatory authority[39] and guaranteed grid access, a number of cash and tax subsidies are available to aid in the development of biomass. Federal subsidies are available to developers of biomass power plants. The amount of the subsidy depends upon the efficiency rating of the plant. The government exempts imported and domestic equipment from excise duties, and offers accelerated depreciation treatment for energy efficiency and biomass power generation equipment. Finally, the government offers a 10-year tax holiday that applies to biomass power plants.[40]

Regarding the natural resources available for the facilitation of biomass development, abundant sugarcane bagasse is the main raw material for biomass power generation in India. India is the world's second largest sugarcane producing country, following Brazil.[41] In India, bagasse electricity production is generally combined with the production of sugar, with a portion of the electricity used to power the mill, and the excess sold into the grid. The cogeneration of power with sugar production strengthens the overall financial condition of the project.

In order to promote sufficient biomass supply for each facility, sugarcane mills are required to be located a minimum distance from each other by state law. For example, in Uttar Pradesh, India's leading sugar cane growing region,[42] mills may not be located within a 15 km radius of each other.[43]

CASE STUDY: INDIA

Water-Efficient Sugarcane Farming in India[1]

Sugarcane is traditionally a water-intensive crop, requiring steady irrigation for a full eighteen-months to two-year growing period. Without abundant local water resources, sugarcane requires extensive irrigation that competes against other food crops and can be costly both financially and ecologically. Conventional sugarcane farming also relies heavily on fertilizers and pesticides.

An innovation pioneered by a local farmer in Karnataka, India, replaces the practice of soil flooding with providing enough water to maintain soil moisture. The method involves reducing the number of irrigation channels, building up the soil's organic content and earth fauna, eliminating synthetic fertilizers and pesticides, and adopting no-till practices. Elimination of the water flood and these other changes enhance soil aeration and fertility, and reduce susceptibility to disease.

The method reduces water requirements by as much as seventy-five percent compared to conventional sugarcane farming, increases farming profits by eliminating costs of fertilizer and pesticides, better preserves the soil, and produces comparable or better yields.

Farming associations, such as the Organic Farmers Club, teach these and other techniques; however, these practices have yet to be institutionalized in government policy.

1 *See* Special Unit for South-South Cooperation, UN Development Programme, *Water-efficient sugarcane farming; India, in* Examples of Successful Economic, Environmental and Sustainable Livelihood Initiatives in the South 102 (Sharing Innovative Experiences Series, vol. 3, 2000), *available at* http://tcdc.undp.org/Sie/experiences/vol3/Water-efficient.pdf; Food and Agriculture Organization of the United Nations, *Farmers Innovations, Community Development and the Ecological Management in Organic Agriculture, Case Study 1: No-till sugar cane cultivation with alternate row irrigation, Belgaum, Karnataka, India, in* Organic agriculture, environment and food security (Nadia El-Hage Scialabba & Caroline Hattam, eds., 2002), *available at* http://www.fao.org/DOCREP/005/Y4137E/y4137e07.htm.

The Indian Renewable Energy Development Agency Limited ("IREDA"), a government-owned corporation that promotes, develops and finances renewable energy and energy efficiency projects, requires biomass power plant seeking financing to demonstrate that, for each MW of nameplate capacity, a plant will have access to at least 10,000 tons of biomass material each year in close proximity to the plant, and an additional 10,000 tons of surplus in the surrounding area. As a general guideline, in order to ensure supply of biomass, IREDA prohibits more than one biomass power plant in a single district and a minimum distance of at least 50 km between power plants. IREDA further requires that the quality of the biomass material have at least 2,000 kilocalories per kilogram. Finally, to be eligible for financing, the cost of the plant may not exceed U.S. $800 per KW nameplate capacity, depending upon boiler configuration and cooling system.

In the context of a private market, India's laws provide a degree of protection from over-competition for supply of biomass; this is particularly important where land ownership is predominately private, as it is in India. Even with these protections, power plant owners still have ample incentive to pay a competitive rate for biomass supply, and to maintain good relationships with farmers. We are aware of examples of power plant owners providing their farm suppliers with financial assistance to purchase fertilizer, offering education on agricultural techniques, and even access to company health care facilities, schools, and other services.[44]

Conclusions

China and India both plan for biomass power generation to increase significantly. Both countries have provided preferential electricity tariffs and guaranteed sale of biomass and other renewable energy to the power grid. Beyond these steps, the approaches taken by the countries diverge.

India has developed an innovative institutional approach that is appropriate to its market economy and legal system. It relies on private sector generation of power and limiting (without eliminating) competition for the supply of biomass through state law and IREDA's lending guidelines. In contrast, China's efforts focus on financial support of developing biomass resources and technology and financial support for the purchase of biomass. China's technology development efforts include research and development to increase the efficiency of traditional biomass technologies and an innovative program to develop microturbine biomass facilities in an effort to adapt to the institutional and market conditions facing biomass technology in China.

Notably, China and India's policies focus primarily on the promotion of the use of biomass. Our survey did not identify laws or policies designed to address water and food security issues. Both China and India will need to more fully integrate water resource planning into their energy policies as biomass power generation is scaled up to meet energy demand.

Endnotes: Overcoming Institutional Barriers to Biomass Power in China and India

1 Biomass includes crop residues, waste by-products of crop processing (e.g., rice straw, husk, wheat straw, coarse cereals, straws and husk, sugarcane baggasse tops, etc.), woody produce of forests and plantations, and biomass acquired from growths in wastelands.

2 International Energy Agency, Renewables in Global Energy Supply: An IEA Factsheet (2007), *available at* http://www.iea.org/textbase/papers/2006/renewable_factsheet.pdf.

3 *See* V. Dornburg & A.P.C. Faaij, *Assessments of future global biomass potentials and their linkage to specific local conditions such as water, land-use, biodiversity, food production and economy*, 2007 Proceeding Eur. Biomass Conf. Eur. & Exhibition 383; *see also* International Energy Agency, Energy to 2050: Scenarios for a Sustainable Future (2003), *available at* http://www.iea.org/textbase/nppdf/free/2000/2050_2003.pdf; Thomas B. Johansson et al., *Renewable Fuels and Electricity for Growing World Economy, in* Renewable Energy Sources for Fuel and Electricity 1 (Thomas B. Johansson et al. eds., 1992).

4 *See generally* Veronika Dornburg et al., Biomass Assessment, Assessment of global biomass potentials and their links to food, water, biodiversity, energy demand and economy (2008).

5 *See, e.g.,* Martin Donohoe & Emily P. Garner, *Health Effects of Indoor Air Pollution From Biomass Cooking Stoves*, Medscape Today, May 19, 2008, http://www.medscape.com/viewarticle/572069?src=mp&spon=42&uac=5243EK.

6 *Id.*

7 New Mexico Biomass Information Clearinghouse, Benefits of Using Biomass, http://www.emnrd.state.nm.us/emnrd/biomass/benefits.html (last visited Apr. 18, 2009).

8 U.S. EPA Combined Heat & Power P'ship & Asia Pacific P'ship on Clean Development & Climate, Facilitating Deployment of Highly Efficient Combined Heat and Power Applications in China 10 (2008), *available at* http://www.epa.gov/chp/documents/chpapps_china.pdf.

9 World Coal Institute, Coal Info: India, http://www.worldcoal.org/pages/content/index.asp?PageID=402 (last visited April 20, 2009).

10 *See* Fact Sheet, Nat. Res. Def. Council, Dirty Coal Is Hazardous to Your Health: Moving Beyond Coal-Based Energy (2007), *available at* http://www.nrdc.org/health/effects/coal/coalhealth.pdf.

11 E. M. Morrison, Ash back: Research Looks at Recycling Waste Ash for Fertilizer, Apr. 11, 2008, http://www.farmandranchguide.com/articles/2008/04/11/ag_news/production_news/pro17.txt.

12 *See* Eric D. Larson, *Modernizing Biomass Energy, in* Climate Change and Development 271, 284 (2000), *citing* J. Li et al., Assessment of Biomass Resource Availability in China (1998), *available at* http://environment.yale.edu/topics/786; *see also* Center for Renewable Energy Development et al., Biomass Support for the China Renewable Energy Law: International Biomass Energy Technology Review 1-2 (2006) [hereinafter CRED], *available at* http://www.nrel.gov/docs/fy07osti/40626.pdf.

13 *See* Larson, *supra* note 12, at 284.

14 *See* CRED, *supra* note 12, at 2.

15 *See infra*, Table 1.

16 *See, e.g.,* N.H. Ravindranath & D. O. Hall, Biomass, Energy & Env't 14 (1995) (examining several challenges to developing markets for renewable energy in India, including ensuring the maintenance of a sustainable supply of biomass).

17 *See generally* Stéphane Straub, *Infrastructure & Growth in Developing Countries: Recent Advances & Research Challenges* (World Bank, Policy Research Working Paper No. 4460, 2008), *available at* http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1080475# (examining the connection between development of transportation infrastructure and economic growth).

Endnotes: Overcoming Institutional Barriers to Biomass Power in China and India *continued on page 64*

[18] *See* Evan N. Turgeon, *Federal Forests, Biomass, & Ethanol: Energy Security Sabotaged*, 39 Envtl. L. Rep. News & Analysis 10140, 10148 (2009) (noting that "harvesting and transporting biomass is the greatest cost constraint to its use").

[19] *See, e.g.,* Ravindranath & Hall, *supra* note 16, at 19-30 (examining the many domestic and industrial uses of biomass in India).

[20] *See* Mario Giampietro et al., *Feasibility of Large-Scale Biofuel Production*, 47 BioScience 587 (1997) (finding that water requirements will severely limit the expansion of biofuels production); *but see* Göran Berndes et al., *The feasibility of large-scale lignocellulose-based bioenergy production*, 20 Biomass & Bioenergy 371 (2001) (contradicting Giampietro et al., finding that water requirements are not a severe limitation on biofuels production).

[21] The renminbi is the currency of the People's Republic of China.

[22] Fredrich Kahrl & David Roland-Holst, *China's Carbon Challenge: Insights from the Electric Power Sector 22* (Ctr. for Energy, Res. & Econ. Sustainability, Research Paper No. 110106, 2006), *available at* http://are.berkeley.edu/~dwrh/CERES_Web/Docs/CCC_110106.pdf.

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[26] The Renewable Energy Law (promulgated by the Standing Comm. Nat'l People's Cong., Feb. 28, 2005, effective Jan. 1, 2006), arts. 14-15 (P.R.C.), *available at* http://www.renewableenergyaccess.com/assets/download/China_RE_Law_05.doc.

[27] *See* CRED, *supra* note 12.
[28] *Id.*
[29] *Id.*
[30] *Id.*
[31] *Id.*
[32] *See* CRED, *supra* note 12.
[33] *Id.*
[34] Ministry of New and Renewable Energy, History MNRC, http://mnes.nic.in/history.htm (last visited Apr. 22, 2009).
[35] *See* Shoumyo Majumdar, Renewable Energy and Energy Efficiency P'ship, The Current Scenario of Developments In Renewable Energy In India (2008), *available at* http://www.reeep.org/file_upload/5272_tmpphpJPhOrP.pdf; *see also* The Energy Conservation Act, 2001, No. 52, Acts of Parliament, 2001, *available at* http://powermin.nic.in/acts_notification/energy_conservation_act/index.htm.
[36] The Electricity Act of 2003, 2003, No. 36, Acts of Parliament, 2003, *available at* http://aptel.gov.in/pdf/The%20Electricity%20Act_2003.pdf.
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